Auto detection of wood texture orientation by Radon transform

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Abstract: A novel and efficient approach for detecting wood texture orientation by computer was presented. Four Matlab functions were tried to describe the relative position and orientation of wood texture pixels, to detect texture shape and to create skeletal lines image of wood texture, and BWMORPH function was found the best one. Then by Radon transform, it generated a signature composed of 180 values, each value summing up the size of texture lines that are shaped along that angle, and a two dimensional curve plot was drawn to represent the texture orientation of wood. Furthermore, it analyzed texture orientations of forty species as well as their general statistic laws, classified by softwood, hardwood, radial section and tangential section, and the results showed that texture orientation laws described by Radon transform plot and their extracting datum were in accord with the impression of wood texture that people possessed in daily life, which confirmed the validity of this new approach and their appealing utilization potentials.

Keywords: Wood; Texture; Orientation; Radon transform; Digital image processing
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Introduction

Among the features that describe visual properties of an image, the directionality should be studied as a distinguished feature. In the model of visual interpretation of image content, the image visual properties are mainly related to the largest foreground components, and among their features the shape, the texture and the orientation play a major role. It is assumed that orientation of objects (texture) within an image is a key attribute in the definition of the similarity with other images. Following this assumption, a metric for image classification based on orientation in the two-dimensional space can be defined, which is quantified by signatures composed of angular spectra of image components.

The microscopic cellular structure of wood, including annual rings and rays, produces the characteristic grain patterns in different wood species. The grain pattern is also determined by the plane in which the logs were cut at saw-mill. When cut in transverse sections, the annual rings appear like concentric bands, with rays extending outward like the spokes of a wheel. When cut longitudinally, there are two different planes, tangential and radial. Tangential sections are made perpendicular to the rays and tangential to the annual rings and face of the log, where the annual rings appear in irregular, wavy patterns. Radial sections are made along the rays or radius of the log, at right angles to the annual rings, where the rings appear like closely-spaced, parallel bands. All these characteristic texture patterns make wood more apparent and special than other materials.

Until now, quantification of wood texture has not accomplished yet, and some of its work should still be carried out further, such as the quantitative detection of wood texture orientation. Someone has pointed out the potential of Fast Fourier Transform (FFT) in realizing it, but by theoretical analysis, Radon transform was found more competent than FFT in the detection of texture orientation (Wang 1999; Guo 2003).

In recent years the Radon transform has received much attention (Deans 1983). This kind of transformation is able to extract lines (curves in general) from noisy background, and transfer a two dimensional image into a domain of line parameters, where each line in the image will give a peak positioned at the corresponding line parameters. This has led to many line detection applications in image processing, computer vision and array processing (Rey 1990; Wang 2001).

Therefore, auto detection of wood texture orientation by Radon transform was studied, with an assistant of MATLAB 6.5 in this paper.

Materials and methods

Materials

Forty species, including fourteen conifers and twenty-six broad-leaved, were selected according to the rule of covering main textural features of most species. All specimens were made truecolor images of 512 by 512 pixel.

Methods

Some Matlab functions were employed to serve some special actions in detecting texture shapes, executing Radon transform and ultimately plotting texture orientations of wood. To introduce these functions, it selected a typical radial section image and a typical tangential section image of wood as illustration (Fig. 1).

Open image

The 'IMREAD' function was used to open graphic files of almost any format, and read the intensity of pixels as a two-dimensional (M-by-N) array or a three-dimensional (M-by-N-by-3) array in current workspace.

Convert image format

The truecolor images should be converted into grayscale intensity images or binary images for a purpose of dimension reduction, and the feasible Matlab functions are 'RGB2GRAY' and 'IM2BW'.

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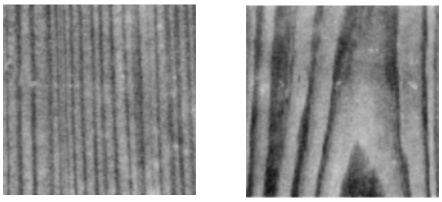


Fig. 1 Typical radial and tangential wood images
a. radial section b. tangential section

Detect texture shape of image

Four Matlab functions, i.e., 'IMCONTOUR', 'EDGE', 'BWPERIM' and 'BWMORPH', were used to detect texture shape. IMCONTOUR draws a contour plot of an input intensity image, automatically setting up the axes so their orientation and aspect ratio match the image, shown in Fig. 2 (A). EDGE takes an intensity image as its input, and returns a binary image of the same size as input image, with 1's where the function finds edges and 0's elsewhere, shown in Fig. 2 (B). BWPERIM will return a binary image containing only the perimeter pixels of objects in the input image, acting a role of borderlines detection, shown in Fig. 2 (C). BWMORPH performs morphological operations on the input binary image, and returns a binary image containing only the skeletal pixels of objects in the input image, acting a role of skeletal lines detection, shown in Fig. 2 (D).

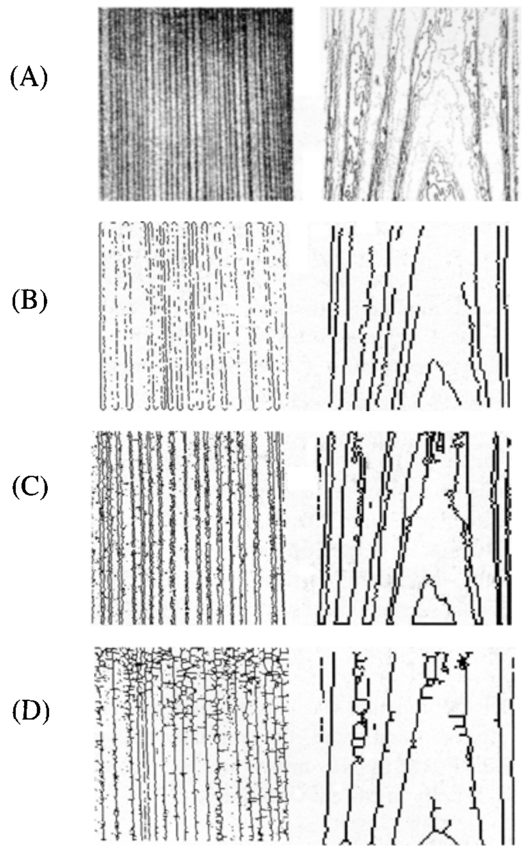


Fig.2 Detection results of texture shapes by different functions
(A) by IMCONTOUR; (B) by EDGE;
(C) by BWPERIM; (D) by BWMORPH

Experimental results showed, IMCONTOUR could not simplified depict the shapes of texture, and EDGE did not achieve an intact shape of weak texture as wood, thereby either of them is not the appropriate texture detection function. Whereas both BWPERIM and BWMORPH can detect a concise and intact texture shapes.

Radon transform

The Radon transform computes projections of an image matrix along specified directions. It is defined as:

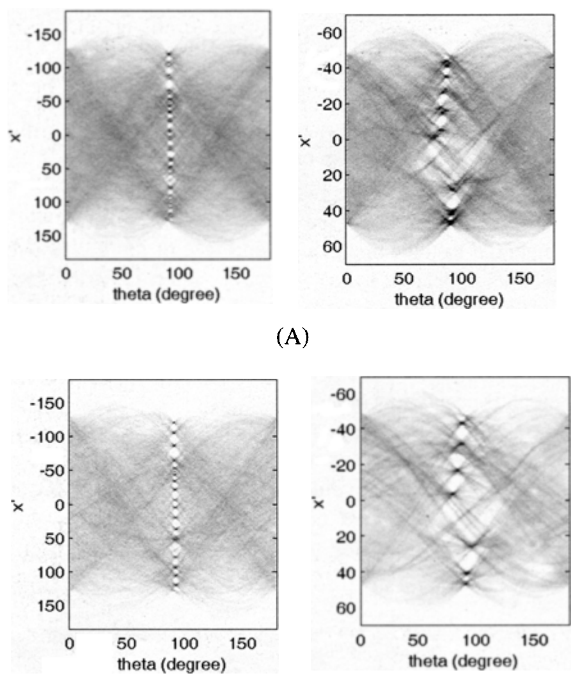
$$R_\theta(\rho) = \int_{-\infty}^{+\infty} f(x'\cos\theta - y'\sin\theta, x'\sin\theta + y'\cos\theta)dy'$$

Where

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

The Radon operator maps the spatial domain $f(x,y)$ to the projection domain (ρ,θ), in which θ is the angle and rho the smallest distance to the origin of the coordinate system. The Radon transform for a large number of angles is often displayed as an image. It generates a signature composed of 180 values, one for each angle in [0°-179°] range, in 1° increments, each value summing up the size of the image components (i.e., lines) that are shaped along that angle.

Some very bright spots are found in the Radon transform plot, and positions of these spots showed parameters of the lines in the original image, shown in Fig. 3, and compare with Fig.1. The positions and arrays of spots in Radon transform plot of BWPERIM lines and BWMORPH lines are very similar, and only the number of bright spots in Radon transform plot of BWPERIM lines is more than that of BWMORPH lines. This shows that both two functions are able to detect orientations of texture.



(B)

Fig. 3 Radon transform of BWPERIM lines and BWMORPH lines
(A) of BWPERIM lines; (B) of BWMORPH lines.

Plot texture orientation

In Radon transform plot, the location of each bright spot will correspond to one or many strong lines in the original image. If these strong peaks in the Radon transform matrix were found, then the orientation of texture would be clear. So we use 'MAX' function to search out the max values of each theta column in Radon transform matrix, and make them Y-coordinate, with thetas as X-coordinate, then a two dimensional curve plot presents, as shown in Fig. 4 and Fig. 5, and compare with Fig. 1.

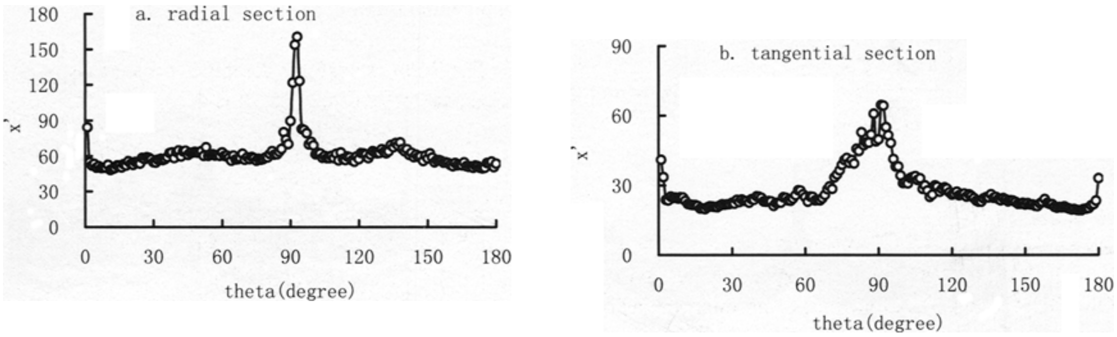


Fig. 4 Texture orientation plot from RT of BWPERIM lines

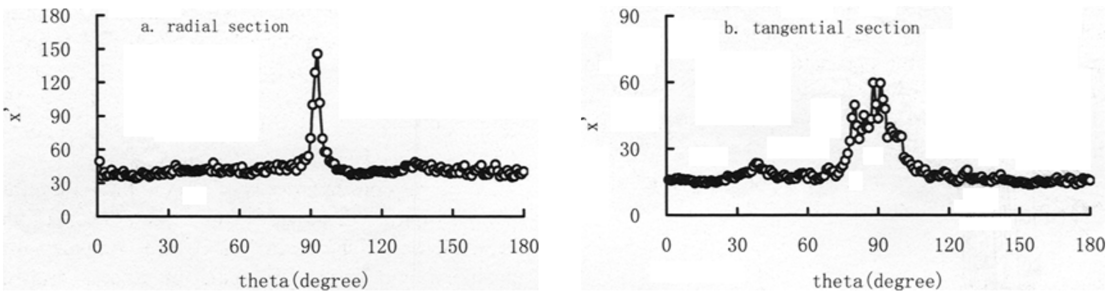
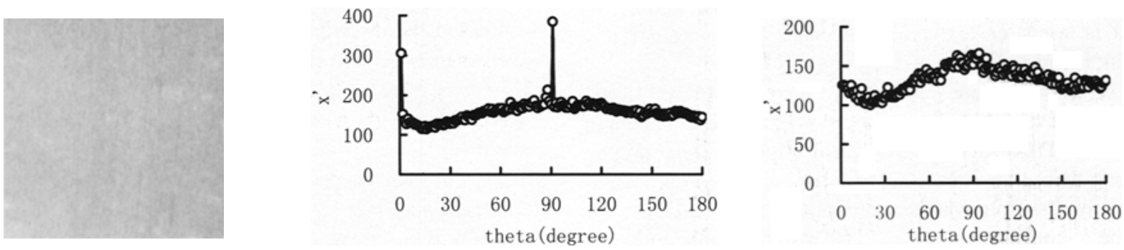


Fig. 5 Texture orientation plot from RT of BWMORPH lines

By texture orientation plot, we found that plot either from RT of BWPERIM lines or BWMORPH lines will be a definite orientation indicator for some obvious texture species, and their plot curves are very similar. But for some textureless or texture not obvious species, such as *Betula platyphylla*, the texture orientation plot from RT of BWPERIM lines differs from that of BWMORPH lines, as shown in Fig. 6. Plot from BWPERIM lines has an obvious peak value about 400 at 90 degree, and less than 180 at other degrees; while in plot from BWMORPH lines, there is no high peak as about 400 at 90 degree, and its curve shape shows that there is no definite texture orientation in original image. So we can conclude that for some weak texture and textureless species, BWMORPH is better than BWPERIM in texture shapes detection.



(A) (B) (C)

Fig. 6 Texture orientation plot of *Betula platyphylla*

(A) Original image of *Betula platyphylla*; (B) texture orientation plot from BWPERIM; (C) from BWMORPH.

Matlab codes for texture orientation detection

```
I=imread('image.BMP');
subplot(231),imshow(I),title('Original image')
K=rgb2gray(I);
L=imcomplement(K);
J=im2bw(L,graythresh(L));
subplot(232),imshow(J),title('Binary image')
BW= bwmorph(J,'skel',Inf);
subplot(234),imshow(BW),title('Skeletal lines image')
theta=0:179;
```

```
[R,xp]=radon(BW,theta-90);
subplot(235),imagesc(theta,xp,R);colormap(jet);
xlabel('theta (degree)');ylabel('x''');
title('Radon transform of skeletal lines image');colorbar
M=max(abs(R));
subplot(236);plot(M);
xlabel('theta (degree)');ylabel('x''');
title(' Texture orientation plot');
save thetaplot M -ascii
```

Results and analysis

The texture orientations of softwood and hardwood in radial, tangential sections were investigated, and were drawn texture orientation plots classified by softwood, hardwood and radial, tangential section, as shown in Fig. 7.

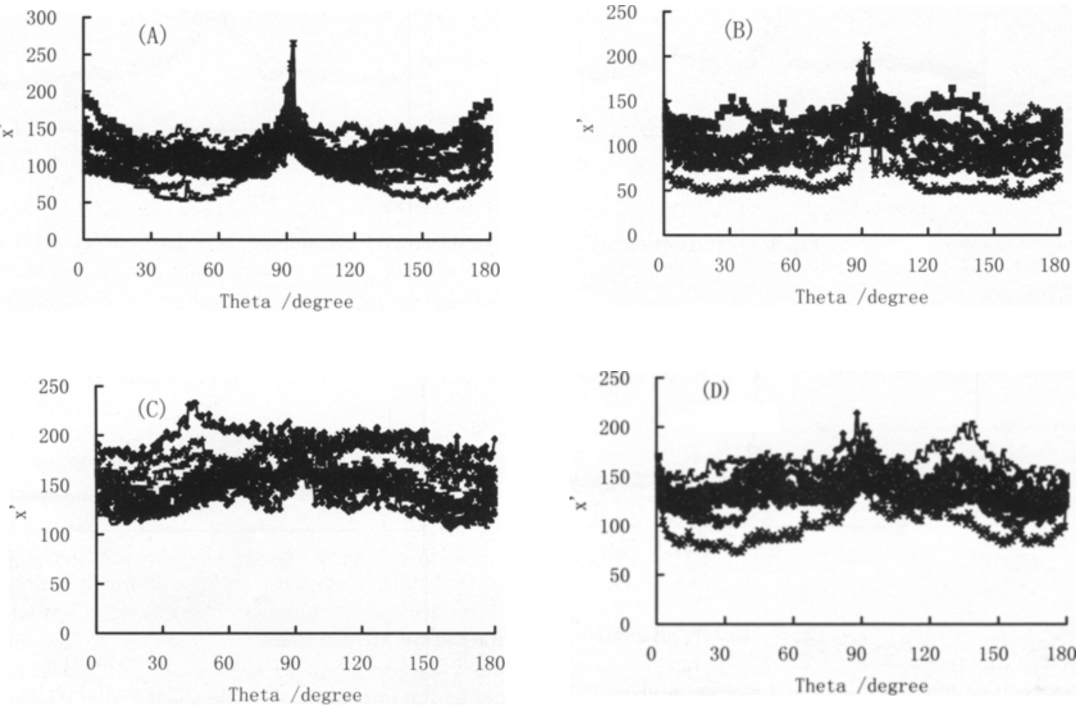


Fig. 7 Texture orientation plot of in radial, tangential sections of softwood and hardwood

(A) Radial texture, softwood; (B) Tangential texture, softwood; (C) Radial texture, hardwood; (D) Tangential texture, hardwood.

In Fig. 7(A) and (B), there was a peak whose kurtosis is very large at direction of 90 degree, which showed texture of softwood has a more definite orientation than that of hardwood, and represented more obviously in radial section of softwood than in tangential section. Fig. 7(C) and (D) showed that texture of hardwood is weak or textureless, because there was not any strong peak found in plot ranged in theta of [0°–179°].

At the same time, there were peaks found near 45 or 135 degree, though not strong, and without a large kurtosis, as shown in Fig. 7(B) and (D), which showed there might be some texture trends along these two directions, and can be verified by tangential section images from whether softwood or hardwood.

From the Y-coordinates of Fig. 7, we also found that curves of every species collocated very near, which showed that there were no big differences in texture intensity among these species, and this could be interpreted for the same kind of objects they are.

Conclusions

The results showed that the texture orientation of wood could be auto detected by computer, with only several Matlab functions. There were four Matlab functions used to detect texture shape and create texture lines image, and BWMORPH function was found the best one, whose action is to extract texture skeletal lines from original image. By Radon transform, it generated a signature composed of 180 values, each value summing up the size of texture lines that are shaped along that angle, and by searching out the max values of each angle column, a plot that describing texture orientation was produced. Finally, the texture orientations of forty species was analyzed and classified by softwood, hardwood and radial section, tangential section, as well as their general statistic laws.

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